

Forage Quality, Mineral Constituents, and Performance of Beef Yearlings Grazing Two Crested Wheatgrasses

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ABSTRACT

In the central Great Plains, crested wheatgrasses [*Agropyron cristatum* (L.) Gaetner and *A. desertorum* (Fischer ex Link) Schultes] are best utilized for early spring and late fall grazing. The principal objective of this study was to determine if beef (*Bos taurus* L.) yearlings grazing 'Ruff' (*A. cristatum*) during the spring grazing season had higher average daily gains and gains per hectare than cattle grazing 'Nordan' (*A. desertorum*). These cultivars were evaluated in grazing trials (four replications) in eastern Nebraska in 1985, 1986, and 1987. The 0.8-ha pastures were seeded in the fall of 1983 on a Typic Argiudoll soil and were fertilized annually with 68 to 90 kg N ha⁻¹. Grazing was for 6 wk each spring by yearling steers with a beginning average weight of 250 kg. Averaged over 3 yr, Ruff produced higher gains per hectare than Nordan (272 vs 245 kg ha⁻¹) probably because it produced more herbage because of its better persistence. At the end of the trial, the average basal cover of Ruff and Nordan were 21 and 6%, respectively. Three-year mean average daily gains were Ruff = 1.28 vs. Nordan = 1.34 kg d⁻¹, which were unexpected, because Ruff generally had higher forage quality as measured by an array of parameters. Ruff forage had a higher, less desirable grass tetany ratio [K/(Mg+Ca)] than Nordan (2.6 vs. 2.3) averaged over 3 yr. Cattle grazing Ruff had lower blood serum Mg levels than cattle grazing Nordan (15.4 vs. 16.2 mg L⁻¹), both of which were below the hypomagnesemia threshold of 18 mg L⁻¹. This condition may have reduced intake and animal gains. These results indicate the need for evaluating pasture and range grass cultivars under grazing conditions.

CRESTED WHEATGRASSES are important perennial cool-season forage grasses in western North America (Rogler and Lorenz, 1983). In the central Great Plains where the native rangeland is comprised primarily of warm-season grasses, crested wheatgrass is best utilized as a short-season grass for early spring and late fall grazing. Crested wheatgrass can be grazed about 6 wk prior to the time when the native rangeland is available for grazing. Spring forage of crested wheatgrass can meet the critical need of beef cows (*Bos taurus* L.) with calves and yearlings for high quality forage. Crested wheatgrass declines in forage quality as it matures in late spring and early summer and in the central Great Plains its productivity during the summer is limited (Newell and Moline, 1978).

Nordan, a tetraploid *A. desertorum* wheatgrass, and Ruff, a diploid *A. cristatum* wheatgrass, are recommended for use in this region. Nordan, which was developed by USDA-ARS at Mandan, ND, is the most widely grown crested wheatgrass in North America. Ruff was developed by USDA-ARS and the University of Nebraska and released in 1974. Both cultivars

were released because of desirable agronomic traits. However, neither was evaluated for forage quality or animal performance prior to release. In recent small plot trials (Lamb et al., 1984; Vogel et al., 1987), Ruff was consistently higher in in vitro dry matter digestibility (IVDMD) than Nordan by approximately 15 g kg⁻¹. In the small plot trials, herbage yields of both cultivars were similar. Small improvements in IVDMD of the same magnitude have significantly improved average daily gains of beef cattle grazing bermudagrass [*Cynodon dactylon* (L.) Pers. var. *dactylon*] (Chapman et al., 1972) and switchgrass (*Panicum virgatum* L.) (Anderson et al., 1988).

The principal objective of this study was to determine if beef yearlings grazing Ruff during early spring had higher average daily gains and gains per hectare than cattle grazing Nordan. Because of the unexpected results obtained during the first grazing season, the study was expanded to include mineral analyses of the herbage and animal blood serum as well as determinations of persistence.

Previous grazing studies with crested wheatgrasses have generally evaluated grazing management practices or compared animal gains to those observed on other forage grasses. This grazing research has been summarized by Mayland (1986). Grazing studies comparing different cultivars of crested wheatgrass have not been reported previously except for palatability trials (Gomm, 1969; Murray, 1984). Limited differences were observed among crested wheatgrasses for visual estimates of palatability in these trials.

Crested wheatgrass forage does not appear to contain significant amounts of toxic compounds except occasionally high levels of nitrates and trans-aconitic acid have been reported (Mayland, 1986). The latter may reduce magnesium availability to livestock, resulting in hypomagnesemia, or grass tetany (Mayland and Grunes, 1979). Ruminant livestock grazing crested wheatgrass in the spring can be affected by grass tetany, resulting in production losses (Mayland, 1986). Recently, Vogel et al. (1989) and Mayland and Asay (1989) reported significant genetic differences among crested wheatgrass strains for grass tetany potential as measured by forage Mg, Ca, and K concentrations expressed as a ratio [K/(Ca + Mg)]. The grass tetany potential for Ruff was higher than that of Nordan (Vogel et al., 1989). In addition to causing grass tetany, low levels of Mg in the diet can lead to inappetence and reduced dry matter intake by livestock (Mosely and Griffiths, 1984; Littledike and Goff, 1987; Scott et al., 1980).

MATERIALS AND METHODS

The study was conducted over three grazing seasons from 1985 through 1987 at the University of Nebraska Agricultural Research and Development Center near Mead, NE, which is located 35 km west of Omaha, NE. Ruff and Nordan crested

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Abbreviations: IVDMD, in vitro dry matter digestibility; ADF, acid detergent fiber; NDF, neutral detergent fiber, FA, ferulic acid; PCA, *p*-coumaric acid; and ADG, average daily gain.

wheatgrass were planted in 0.8-ha pastures during September 1983. Eight pastures were established in a randomized complete block design with four replicate pastures per cultivar. The soil was a Sharpsburg silty clay loam (fine, montmorillonitic, mesic, Typic Argiudoll). In 1984, the pastures were harvested for hay after the grasses headed.

Prior to each grazing season, pastures were burned in early spring about 30 d before grazing to remove residue from the previous year and to control weeds, primarily annual *Bromus* species. Pastures were fertilized with N (NH_4NO_3) as follows: 18 Oct. 1984, 67 kg N ha⁻¹; 6 Aug. 1985, 90 kg N ha⁻¹; 28 Aug. 1986, 84 kg N ha⁻¹; and 16 April 1987, 84 kg N ha⁻¹. Broadleaf weeds were controlled by early spring or fall applications of 2,4-D [(2,4-dichlorophenoxy) acetic acid] at rates of 1.1 or 2.2 kg ha⁻¹. Alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl)-acetanilide) was applied in late summer of 1984 and 1985 at a rate of 2.2 kg ha⁻¹ to control annual *Bromus* spp.

Pastures were grazed continuously by cross-bred Angus × Hereford × Simmental yearling steers in the spring of 1985, 1986, and 1987. Experimental animals represented the middle weight group of a larger number of steers wintered to gain approximately 0.5 kg animal⁻¹ d⁻¹. Yearlings had ad libitum access to water and salt. Initial steer weights at the beginning of the grazing season averaged 260, 220, and 280 kg per animal, respectively, in 1985, 1986, and 1987. Steers were weighed following an overnight shrink at the beginning and end of the grazing trial each year.

Four steers were allocated randomly to each 0.8-ha pasture at the beginning of each grazing season. On 13 May 1986, two steers were removed from two Nordan pastures because those pastures had only 43% of the herbage mass of Ruff pastures in those replicates. Likewise, on 6 May 1987, two steers were removed from three Nordan pastures and one steer was removed from the other Nordan pasture due to lower herbage mass than the corresponding Ruff pasture. Stocking density was adjusted to keep herbage allowance similar between cultivars. Initial stocking density was set to allow little herbage mass to remain following the brief spring grazing season and was based on previous small plot research at Mead (Vogel et al., 1987) in which crested wheatgrass produced about 4.5 Mg ha⁻¹ herbage during the spring growing season.

Forage sampling periods were initiated and terminated each year to coincide with the first and last day of grazing, respectively. Herbage mass was determined weekly by harvesting all forage above a 2.5-cm cutting height in three randomly placed 30-by 182-cm frames in each pasture. Previously harvested areas were not reharvested using the sampling frames. Forage samples for quality analyses were taken on the same days as the herbage mass samples from (i) the portion of the plants the animals were grazing which was visually assessed as the top 1/3 of the plants (grazed herbage), (ii) all herbage above 2.5 cm (total herbage), and (iii) from four caged enclosures (1.2 by 1.5 by 1.5 m) per pasture (ungrazed herbage). Only previously unclipped plants within an enclosure were sampled for the ungrazed herbage samples. The grazed and total herbage quality samples for a specific date and pasture were obtained by collecting approximately six sub-samples at random in a pasture and compositing samples by sample type. Ungrazed samples were obtained by sampling herbage above 2.5 cm in each of the four cages in a pasture. Samples were dried in a forced-draft oven at 55 °C to constant weight, ground to pass a 1-mm screen in a Thomas Wiley¹ mill with stainless steel blades, and stored in plastic vials at room temperature until analyzed.

Estimates of forage digestibility (IVDMD) used the two-stage method of Tilley and Terry (1963) with minor modifi-

cations (HgCl_2 and Na_2CO_3 were not added after the first step). The rumen fluid was a mixture taken from two fistulated steers maintained on separate diets of alfalfa (*Medicago sativa* L.)-smooth bromegrass (*Bromus inermis* Leyss.) hay or ground corn (*Zea mays* L.) cobs. Crude protein concentration ($\text{N} \times 6.25$) was determined following the Kjeldahl procedure (A.O.A.C., 1975). Neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and lignin (permanganate-oxidation) concentrations were sequentially determined as described by Van Soest and Robertson (1980). Alkali-labile phenolics, ferulic acid (FA), and *p*-coumaric acid (PA) were extracted and analyzed from air-dried NDF residues with high performance liquid chromatography (HPLC) methods (Gabrielsen et al., 1990).

Forage samples were analyzed for Ca, Mg, and K concentration each year. In 1986, the forage material was also analyzed for S, P, Zn, Mn, Cu, and Fe concentration to screen for possible differences in these elements between the two cultivars. Blood was collected from all yearlings in the study by jugular puncture on three dates in 1986 and five dates in 1987. The collection dates generally coincided with the beginning, middle, and end of the grazing season each year. Elemental analyses for both forage and blood serum samples were conducted using procedures described by Vogel et al. (1989). In brief, both forage and blood serum samples were digested in a 3:1 nitric-perchloric acid solution and diluted with a 1 g L⁻¹ La (as LaCl_3) solution. Magnesium and Ca were analyzed by atomic absorption and K by flame emission. Analytical accuracy was typified by a 99, 98, and 98% mean recovery of Ca, Mg, and K, respectively, using citrus leaf samples from the National Institute of Standards and Technology (SRM-1572). Phosphorus was determined colorimetrically as molybdovanado-phosphoric acid and other elements were determined by atomic absorption. The grass tetany ratio, $\text{K}/(\text{Ca} + \text{Mg})$, was calculated on an equivalents per kilogram basis.

Prior to the initiation of the grazing trial, soil samples were taken from each pasture. Soil from 0- to 30-cm and 30- to 60-cm depths was collected and composited separately for each pasture. Soil samples were analyzed by the University of Nebraska Soil Testing Lab for the routinely determined soil characteristics.

At the end of the grazing trial in 1987, basal cover of each cultivar was determined by using an inclined 10-point frame. The frame was placed at 6-m intervals along four 60-m transects located in each pasture (40 frames/pasture). Each point intercept was recorded as either bare ground, mulch (dead plant residue), or crested wheatgrass.

The experimental design was a randomized complete block with four replicates. Analyses of variance (ANOVA) procedures were used to determine if mean differences between cultivars were significant for the traits evaluated (Steel and Torrie, 1960). Since in 1986 and 1987 some yearlings were periodically removed from the Nordan pastures to maintain a similar herbage allowance between cultivars, average daily gains were determined using data from animals that remained in the test pastures for the duration of a grazing season. Gains per hectare were calculated as mean average daily gain by grazing days for each pasture.

RESULTS AND DISCUSSION

Stands

Annual precipitation for 1985, 1986, and 1987 was 665, 965, and 772 mm, respectively so moisture was not a limiting factor. Precipitation distribution among and within years was variable, as is typical in the Great Plains (Fig. 1). Excellent uniform stands were present on all pastures at the beginning of the study, so no initial stand data were collected. Excellent stands persisted throughout the 1985 grazing season. By the spring of 1986,

¹Names of products are included for the benefit of the reader and do not imply endorsement by the USDA or the Univ. of Nebraska.

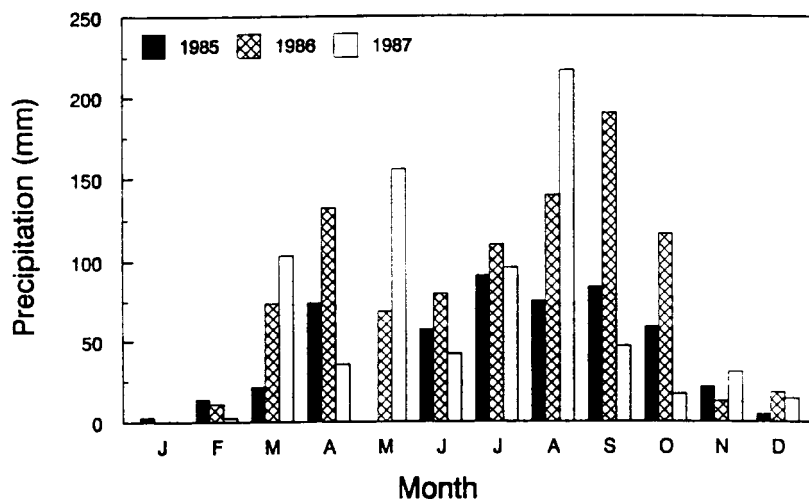


Fig. 1. Precipitation at Mead, NE, in 1985, 1986, and 1987.

stands in the Nordan pastures were diminishing and the plants in the Nordan pastures were not as robust as the previous year. By the fall of 1987, the basal cover of Ruff was $21 \pm 1\%$ versus $6 \pm 2\%$ for Nordan. Because of the loss of stand in the Nordan pastures, stocking density was reduced on Nordan pastures in 1986 and 1987. The loss of stands in the Nordan pastures was due to crown-rot diseases possibly caused by *Helminthosporium* or *Fusarium* spp., which were previously implicated in stand losses of crested wheatgrass in this region (Lamb et al., 1984). Ruff was not affected and maintained excellent stands throughout the study.

Herbage Mass and Allowance

Herbage mass of Ruff and Nordan did not differ in 1985 and 1986 when averaged over weekly samples and pastures (Table 1). In 1985, there were no differences between the cultivars for herbage mass on any sampling date (individual sampling date data not shown). However, Ruff pastures had more herbage mass on the first sampling date in 1986 and during the latter part of the 1986 grazing season herbage mass in two of the four Nordan pastures averaged less than one-half of the herbage mass in corresponding Ruff pastures. For this reason, stocking density in those pastures was reduced. Ruff produced significantly more herbage mass than Nordan in 1987 (averaged over sampling dates, Table 1) because of better stands. Ruff pastures had significantly more herbage mass than Nordan for the first five sampling

dates but there were no differences for the last two sampling dates in 1987.

Stocking density was reduced on Nordan pastures in 1986 and 1987 after 14 d of grazing to equalize herbage allowance between cultivars. Average herbage allowance for Ruff vs Nordan expressed as kilograms per animal was 362 vs. 377 in 1985, 165 vs. 165 in 1986, and 142 vs. 151 in 1987. Although herbage allowance differed among years, the average herbage allowance was very similar between the cultivars within years due to the reductions in stocking density that were made in the Nordan pastures.

Forage Quality

Data from the total herbage samples are not presented because the results were consistent with data from grazed herbage and ungrazed herbage samples. In 1985 when pastures of both cultivars were in good condition, ADF and lignin concentrations were significantly lower and IVDMD was higher in grazed herbage of Ruff (Table 2). Superior forage quality of Ruff was also indicated by lower PCA concentration and higher FA/PCA ratios in the forage cell walls (NDF is considered to be cell wall material). In addition, PCA concentration in the forage cell walls increased at a slower rate in Ruff throughout each grazing season and was highly correlated ($r > -0.95$, $P \leq 0.001$) with changes in IVDMD of both cultivars (data not shown). In a grazing trial of three switchgrass strains, lower levels of PCA and higher FA/PCA ratios in the forage cell wall were strongly associated with forage digestibility and animal performance (Gabrielsen et al. 1990). No differences between the cultivars for CP or FA were apparent. In 1986 and 1987 NDF was slightly higher in Ruff for grazed herbage and in 1987 for ungrazed herbage (Tables 2 and 3). During 1986 and 1987, the other forage quality parameter values were similar or if different indicated a slight superiority of Ruff compared to Nordan (Tables 2 and 3). Based on visual observations in the pastures, Ruff was perceived to have higher forage quality because of greater succulence, leafiness, and later flowering.

Table 1. Herbage mass of two crested wheatgrass cultivars during three grazing seasons at Mead, NE.

Cultivar	Herbage mass†			3-yr mean
	1985	1986	1987	
	kg ha ⁻¹			
Ruff	1790	814	700*	1101
Nordan	1860	674	523	1018
SE	186	109	92	134

* Indicates means are significantly different at the 0.05 level of probability.

† Values are the means of six (1985) and seven (1986 and 1987) sampling dates.

Table 2. Forage quality constituents in grazed herbage of two crested wheatgrass cultivars during three grazing seasons at Mead, NE.

Cultivar	IVDMD†	CP	NDF	ADF	Lignin	FA	PCA	FA/PCA
		g kg ⁻¹ dry matter			mg g ⁻¹ NDF			
1985								
Ruff	753*	237	538	258*	30*	4.3	2.9*	1.84*
Nordan	733	222	546	281	33	4.3	3.7	1.46
SE	2	5	5	3	1	0.1	0.1	0.02
1986								
Ruff	658	157	640*	307*	32‡	3.9	3.7*	1.22*
Nordan	662	155	632	319	35	3.8	4.1	1.03
SE	5	3	2	2	1	0.1	0.1	0.02
1987								
Ruff	702*	229	592*	274	34	4.1	4.0	1.21*
Nordan	682	235	578	282	36	4.0	4.4	1.07
SE	3	3	2	4	1	0.1	0.2	0.02
3-yr mean								
Ruff	704	208	590	280*	32*	4.1	3.5*	1.42*
Nordan	692	203	586	294	34	4.0	4.0	1.19
SE	9	9	9	7	1	0.1	0.2	0.09

‡, * Indicates means are significantly different at the 0.1 and 0.05 levels of probability, respectively.

† IVDMD = in vitro dry matter digestibility; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Lignin = permanganate lignin; FA = ferulic acid; PCA = *p*-coumaric acid.

Cattle Gains

In 1985, average daily gains (ADG) of cattle grazing Nordan were higher than those grazing Ruff (Table 4). Since stocking rates were the same, gains per hectare also were higher on Nordan than on Ruff (Table 4). These results were unexpected because herbage mass in 1985 was similar for the two cultivars (Table 1) and Ruff and higher quality forage as determined by most forage quality parameters (Tables 2 and 3) particularly for the grazed herbage samples.

In 1986 and 1987, ADG did not differ among cattle grazing Ruff and Nordan. Ruff produced more kilograms of beef per hectare than Nordan in 1986 and 1987 but the differences were not significant. Averaged over 3 yr,

there were no differences between cultivars for ADG but Ruff produced more gain per hectare because of more herbage mass in 1986 and 1987 due to better stands that permitted higher stocking densities. The ADG obtained for the yearlings grazing both cultivars were higher than or comparable to gains obtained for cattle in previous studies evaluating crested wheatgrass (Malechek, 1986; Hart et al., 1983).

Since some research (Moseley and Griffiths, 1984; Littledike and Goff, 1987; Scott et al., 1980) indicates that Mg deficiencies can affect forage intake and subsequently livestock gains, the study was expanded to include analyses of forage and blood serum mineral concentrations to attempt to explain the results.

Table 3. Forage quality constituents in ungrazed herbage from caged enclosures of two crested wheatgrass cultivars during three grazing seasons at Mead, NE.

Cultivar	IVDMD†	CP	NDF	ADF	Lignin	FA	PCA	FA/PCA
			g kg ⁻¹ dry matter			mg g ⁻¹ NDF		
<u>1985</u>								
Ruff	737	228	545	266‡	32	4.5	2.9*	1.85*
Nordan	732	218	544	276	33	4.4	3.4	1.61
SE	3	6	3	3	1	0.1	0.1	0.04
<u>1986</u>								
Ruff	668	162	615	290*	30*	4.2	3.3*	1.37*
Nordan	670	160	615	311	34	3.9	3.8	1.15
SE	6	8	5	2	1	0.2	0.1	0.04
<u>1987</u>								
Ruff	686	216	573*	269	34	3.8	3.4	1.30
Nordan	687	226	551	274	32	3.7	3.8	1.16
SE	8	5	2	2	2	0.2	0.2	0.05
<u>3-yr mean</u>								
Ruff	697	202	577	275	32	4.1	3.2*	1.50*
Nordan	696	201	569	287	33	4.0	3.7	1.30
SE	8	12	10	7	2	0.2	0.2	0.08

‡, * Indicates means are significantly different at the 0.1 and 0.05 levels of probability, respectively.

† IVDMD = in vitro dry matter digestibility; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Lignin = permanganate lignin; FA = ferulic acid; PCA = *p*-coumaric acid.

Table 4. Average daily gain (ADG) and gain per hectare of beef yearlings grazing two crested wheatgrass cultivars during 3 yr at Mead, NE.

Cultivar	1985†		1986‡		1987§		3-yr Mean	
	Gain ha ⁻¹	ADG†	Gain ha ⁻¹	ADG†	Gain ha ⁻¹	ADG†	Gain ha	ADG†
	kg							
Ruff	316¶	1.46¶	226	1.06	272	1.32	272¶	1.28
Nordan	347	1.60	196	1.12	193	1.30	245	1.34
SE	8	0.04	20	0.07	27	0.10	8	0.04

† Four steers per 0.81-ha pasture. Grazing period 17 April to 31 May (44 d).

‡ Average of 4 and 3.3 steers per 0.81-ha pasture for Ruff and Nordan, respectively. Grazing period 30 April to 12 June (43 d).

§ Average of 4 and 2.8 steers per 0.81-ha pasture for Ruff and Nordan, respectively. Grazing duration 22 April to 3 June (42 d).

¶ Indicates the means were significantly different at the 0.1 level of probability.

Table 5. Forage mineral constituents in grazed and ungrazed forage of two crested wheatgrass cultivars during three grazing seasons at Mead, NE.

Cultivar	Grazed†				Ungrazed‡			
	Mg	Ca	K	K/(Mg + Ca)§	Mg	Ca	K	K/(Mg + Ca)
	mg g ⁻¹ dry matter							
	1985							
Ruff	1.3	2.9¶	23.7*	2.4*	1.3	3.1*	24.3	2.4¶
Nordan	1.3	3.2	21.9	2.2	1.3	3.5	24.1	2.2
SE	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1
	1986							
Ruff	1.2	2.8	22.6*	2.5*	1.2	3.2	22.7	2.2
Nordan	1.2	3.0	21.5	2.2	1.2	3.4	22.3	2.1
SE	0.1	0.1	0.2	0.1	0.1	0.1	0.6	0.1
	1987							
Ruff	1.2	2.5	26.0*	3.0*	1.2	2.9¶	28.4*	3.0*
Nordan	1.2	2.8	23.6	2.5	1.3	3.5	27.1	2.5
SE	0.1	0.1	0.3	0.1	0.1	0.2	0.2	0.1
	3-yr mean							
Ruff	1.2	2.8*	24.1*	2.6¶	1.3	3.1¶	25.1	2.5¶
Nordan	1.2	3.0	22.3	2.3	1.3	3.5	24.5	2.3
SE	0.1	0.1	0.2	0.1	0.1	0.1	0.4	0.1

¶, * Indicates the means were significantly different at the 0.1 and 0.05 levels of probability, respectively.

† Forage clipped from the upper one-third of grazed plants.

‡ Whole plant samples from caged enclosures.

§ Calculated on an equivalents per kilogram basis.

Minerals

Ruminants grazing cool-season grasses are subject to grass tetany (i.e., hypomagnesemia) during the early spring and occasionally during autumn (Mayland and Grunes, 1979; Mayland, 1986). Grass tetany is a complex nutritional disorder caused by a deficiency of Mg in the diet or an interference with K or some other constituent with the efficiency of Mg absorption by the animal (Grunes, 1973; Grunes, et al., 1970; Littledike and Goff, 1987). Although the disorder may result in death of the grazing animal, decreases in production due to sub-acute levels of hypomagnesemia causing reduced forage intake or reduced forage digestibility have been described previously (Ammerman et al., 1971; Moseley and Griffiths, 1984; Littledike and Goff, 1987; Scott, et al., 1980). Research on Mg requirements for growing and finishing beef cattle is limited but a range of 0.5 to 2.5 g kg⁻¹ with a maximum level of 4.0 g kg⁻¹ has been established by the NAS/NRC (1984). This range is apparently based on the requirement for calves (NAS/NRC, 1984). Kincaid (1988) indicates that elemental Mg levels in blood serum of cattle should be greater than 18 mg L⁻¹ to maintain good health. Because of the interactions of Mg, Ca, and K in hypomagnesemia, a cation ratio, K/ (Ca

+ Mg), is used to estimate the grass tetany potential of a forage. This ratio should be 2.2 or less for a forage to be safe in terms of its potential for inducing grass tetany in lactating cows (Mayland and Grunes, 1979).

In 1985, the crested wheatgrass cultivars did not differ in Mg content but Ruff herbage contained significantly less Ca than did Nordan (Table 5). This difference was apparent in both grazed and ungrazed herbage. In addition, Ruff had significantly more K in grazed herbage and higher K/ (Ca + Mg) values in both forage treatments than did Nordan. Because of higher K and K/(Ca + Mg) values, Mg absorption by the yearlings probably was less from Ruff herbage than from Nordan. Similar results were obtained on forage collected during 1986 and 1987 (Table 5). Concentrations of other elements (i.e., P, S, Zn, Mn, and Fe) were within normal limits for ruminant requirements (data not shown).

Concentration of serum Mg in 1986 and 1987 was significantly lower in animals grazing Ruff, while differences for Ca and K content were not apparent (Table 6). The lower serum Mg levels in yearlings grazing Ruff may have resulted from a negative effect of the higher K in the forage when compared to Nordan (Table 5). Information on the critical level of Mg (i.e., serum Mg

Table 6. Mineral constituents in the blood serum of yearlings grazing two crested wheatgrass cultivars during two grazing seasons at Mead, NE.

Cultivar	mg L ⁻¹ serum		
	Mg	Ca	K
1986			
Ruff	16.2	86.3*	157
Nordan	16.8	83.8	158
SE	00.5	00.5	2
1987			
Ruff	14.7	68.1	212
Nordan	15.7	68.4	197
SE	00.8	03.0	11
2-yr mean			
Ruff	15.4†	77.2	184
Nordan	16.2	75.8	177
SE	00.2	02.4	8
Normal range (Kincaid, 1988)			
	18 to 23	90 to 120	150 to 230

†, * Indicates significance at the 0.1 and 0.05 levels of probability, respectively.

Table 7. Soil analyses for the crested wheatgrass pastures at Mead, NE for soil samples collected in early spring, 1985.

Soil Characteristic	Sample profile	
	0 to 30 cm	30 to 60 cm
pH	5.8	6.2
Buffer pH	6.5	6.8
Exchange cations Ca (cmol kg ⁻¹)	13.7	15.0
Exchange cations Mg (cmol kg ⁻¹)	5.0	6.3
Exchange cations K (cmol kg ⁻¹)	1.0	0.7
Exchange cations Na (cmol kg ⁻¹)	1.0	0.3
Organic matter (g kg ⁻¹)	26	14

< 18 mg L⁻¹) in beef and dairy cattle blood serum is based primarily on studies with lactating cows (Mayland, 1988; Kincaid, 1988). If this information is applicable to beef yearlings then steers on both pastures were hypomagnesemic. Possibly the lower serum Mg levels in yearlings grazing Ruff may have reduced dry matter intake and digestion efficiency to a greater extent than for animals grazing Nordan pastures. Since we did not collect blood samples in 1985, we have not data to support this hypothesis. Additional research will be needed to determine the effect of low levels of Mg on gains of beef yearlings. The high gains of steers on both pastures and absence of clinical symptoms associated with hypomagnesemia indicate that the acute level of Mg in blood serum for beef yearlings probably is lower than that observed in this study. The results also question the validity of extrapolating Mg requirements for calves and lactating cows to beef yearlings.

Mineral concentrations of the soil were within normal ranges for soils of the Great Plains (Table 7) and were adequate for normal plant growth. Soil mineral concentration differences among pastures were minimal (data not shown). In previous small plot research, Vogel et al. (1989) reported that Ruff had higher K and K (Ca + Mg) values than Nordan in herbage collected at heading. The results of this study are consistent with the previous report which indicates that samples from small plots are predictive of forage mineral content from pastures over several grazing seasons.

SUMMARY

Perennial pasture and range grasses should establish easily and persist under grazing conditions, and they need to produce high yields of animal products. In this study, excellent gains were made by beef yearlings on both cultivars. Ruff produced more beef per hectare than Nordan because of its better persistence. Because Ruff had higher IVDMD than Nordan in previous studies, it was expected that animals grazing Ruff would have higher daily gains than cattle grazing Nordan. This did not occur even though Ruff generally exhibited higher quality forage as measured by an array of forage quality parameters except for mineral composition. Results confirm that in crested wheatgrass, quality factors other than forage digestibility also may affect animal performance. The combined effects of forage digestibility and mineral content on livestock performance require additional research.

REFERENCES

- Association of Official Analytical Chemists (A.O.A.C.). 1975. Methods of analysis. Washington, DC.
- Anderson, B., J.K. Ward, K.P. Vogel, M.G. Ward, H.J. Gorz, and F.A. Haskins. 1988. Forage quality and performance of yearlings grazing switchgrass strains selected for differing digestibility. *J. Anim. Sci.* 66:2239-2244.
- Ammerman, C.B., C.F. Chicco, J.E. Moore, P.A. Walleghem, and L.R. Arrington. 1971. Effect of dietary magnesium on voluntary feed intake and rumen fermentation. *J. Dairy Sci.* 54:1288-1293.
- Chapman, H.P., W.H. Marchant, P.R. Utley, R.E. Helwig, and W.G. Monson. 1972. Performance of steers on Pensacola bahiagrass, Coastal bermudagrass, and Coastcross-1 bermudagrass pastures and pellets. *J. Anim. Sci.* 34:373-378.
- Gabrielsen, B.C., K.P. Vogel, B.E. Anderson, and J.K. Ward. 1990. Alkali-labile lignin phenolics and forage quality in three switchgrass strains selected for differing digestibility. *Crop Sci.* 30:1313-1320.
- Gomm, F.B. 1969. The palatability of range and pastures grasses in Montana. *Montana Agric. Exp. Stn. Bull.* 619.
- Grunes, D.L., R.P. Stout, and J.R. Brownell. 1970. Grass tetany of ruminants. *Adv. Agron.* 22:331-374.
- Grunes, D.L. 1973. Grass tetany of cattle and sheep p. 113-140. In A.G. Matches (ed.) *Antitoxin components of forages*. CSSA Spec. Publ. 4. ASA, CSSA, and SSSA, Madison, WI.
- Hart, R.H., E.F. Balla, and J.W. Waggoner, Jr. 1983. Gains of steers and calves grazing crested wheatgrass. *J. Range Manage.* 36:483-484.
- Kincaid, K. 1988. Macroelements for ruminants. p. 326-346. In D.C. Church (ed.) *The ruminant animal: Digestive physiology and nutrition*. Prentice Hall, Englewood Cliffs, NJ.
- Lamb, J.F.S., K.P. Vogel, and P.E. Reece. 1984. Genotype and genotype x environment interaction effects on forage yield and quality of crested wheatgrasses. *Crop Sci.* 24:559-564.
- Littledike, E.T., and J. Goff. 1987. Interactions of calcium, phosphorus, magnesium, and vitamin D that influence their status in domestic meat animals. *J. Anim. Sci.* 65:1727-1743.
- National Academy of Sciences/National Research Council. 1984. Nutrient requirements of beef cattle. 6th ed. National Academy of Science, Washington, DC.
- Newell, L.C., and W.J. Moline. 1978. Forage evaluations of twelve grasses in relation to season for grazing. *Nebr. Agr. Exp. Stn. Res. Bull.* 283.
- Malechek, J.C. 1986. Nutritional limits of crested wheatgrass for range livestock production. p. 267-272. In K.L. Johnson (ed.) *Crested wheatgrass: Its values, problems, and myths*. Symp. Proc., Logan, UT. 3-7 Oct. 1983. Utah State Univ., Logan, UT.
- Mayland, H.F. 1986. Factors affecting yield and nutritional quality of crested wheatgrass. p. 215-266. In K.L. Johnson (ed.) *Crested wheatgrass: Its values, problems, and myths*. Symp. Proc., Logan, UT. 3-7 Oct. 1983. Utah State Univ., Logan, UT.
- Mayland, H.F. 1988. Grass tetany. p. 511-523 and 530-531. In D.C. Church (ed.) *The ruminant animal: Its physiology and nutrition*. Prentice-Hall, Englewood Cliffs, NJ.
- Mayland, H.F., and K.H. Asay. 1989. Genetic variability of Mg,

- Ca, and K in crested wheatgrass. *J. Range Manage.* 42:109-113.
- Mayland, H.F., and D.L. Grunes. 1979. Soil-climate-plant relationships in the etiology of grass tetany. p. 123-175. *In* V.V. Rendig and D.L. Grunes (ed.) *Grass tetany*. ASA, CSSA, and SSSA, Madison, WI.
- Moseley, G., and D.W. Griffiths. 1984. The mineral metabolism of sheep fed high- and low-magnesium selections of Italian ryegrass. *Grass For Sci.* 39:195-199.
- Murray, Robert B. 1984. Yields, nutrient quality, and palatability to sheep of fourteen grass accessions for potential use in sagebrush-grass range in southeastern Idaho. *J. Range Manage.* 37:343-347.
- Rogler, G.A., and R.J. Lorenz. 1983. Crested wheatgrass. Early history in the United States. *J. Range Management* 36:91-93.
- Scott, P.R., J.N. Kelley, D.A. Whitaker, and N.D. Cameron. 1980. Marginal magnesium deficiency as a possible cause of reduced voluntary feed intake in commercially managed dairy cows. *Vet. Res. Comm.* 4:225-229.
- Steel, R.G.D., and James H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, Inc., New York.
- Tilley, J.M.A., and R.A. Terry. 1963. A two stage technique for *in vitro* digestion of forage crops. *J. Br. Grassl. Soc.* 18:104-111.
- Van Soest, P.J., and J.B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. p. 49-60. *In* W.J. Pigden, C.C. Balch, and M. Graham (ed.) *Standardization of analytical methodology for feeds*. International Development Research Centre. IDRC-134e. Ottawa, Canada.
- Vogel, K.P., H.G. Jung, and P.E. Reece. 1987. Performance and potential of intergeneric wheatgrass hybrids in the Central Great Plains. *Crop Sci.* 27:8-13.
- Vogel, K.P., H.F. Mayland, P.E. Reece, and J.F.S. Lamb. 1989. Genetic variability for mineral element concentration of crested wheatgrass forage. *Crop Sci.* 29:1146-1150.